ANNUALLY RE-FORMING MINIATURE SORTED PATTERNED GROUND IN THE HIGH DRAKENSBERG, SOUTHERN AFRICA

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ABSTRACT

An analysis of miniature sorted circles and polygons provides the first detailed assessment of sorted patterned ground from a southern African alpine region. Pattern dimensions and particle sorting were determined from two sites in the high Drakensberg. Although the sorted patterns in the high Drakensberg are somewhat polygenetic in developmental origin, they are primarily frost-induced. Miniature sorted patterned ground below 3200 m a.s.l. on the Drakensberg plateau develops annually during the winter months and disintegrates towards summer. The development of miniature sorted patterns within five to six weeks demonstrates the effect of regular freeze–thaw cycles at higher altitudes in the Drakensberg. © 1997 by John Wiley & Sons, Ltd.

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INTRODUCTION

According to Washburn (1956), patterned ground is a 'group term for the more or less symmetrical forms, such as circles, polygons, nets, steps and stripes, that are characteristic of, but not necessarily confined to, mantle subject to intensive frost action' (p. 824). Although patterned ground commonly has a cold-climate origin (Washburn, 1956), several patterns have been attributed to non-frost-related processes (Kelletat, 1985; Hallet, 1990; Van Vliet-Lanoë, 1991; Ahnert, 1994). Dybeck (1957) has ascribed some soil polygon formations to stones sinking into a liquid mud, whereas Kelletat (1985) has observed that rain-splash and rain-wash produce sorted patterns remarkably similar in morphology to those with a frost-related origin. Recently, Bennett (1993) has described stone stripes from North Wales, attributed primarily to sheep disturbing debris cones upslope of the stripes. Numerous authors have, however, produced evidence which indicates that frost-related processes play a significant role in the development of many sorted patterns (e.g. Goldthwait, 1976; Hall, 1979, 1983, 1994; Washburn, 1979; Ballantyne and Matthews, 1982; Van Vliet-Lanoë, 1988, 1991; Hallet, 1990). The formative processes of many types of patterned ground are still poorly understood (French, 1976; Washburn, 1979; Hallet, 1990), in part because different patterns are controlled by different mechanisms (Hallet, 1990), and further, because many are said to have a polygenetic origin (Washburn, 1979).

Washburn (1950, 1956, 1973) has classified patterned ground, utilizing the pattern shape and the sorting of stones as the main criteria. The classification includes the sorted and non-sorted patterns: circles, nets, polygons, steps and stripes. Sorted patterns 'are made prominent because of the segregation of stones and fines' (Gleason *et al*., 1986, p. 216), whereas non-sorted patterns are distinguished by 'ground cover or colour variations' (Krantz, 1990, p. 117). An ongoing problem has been the defining of a standard distinction between large sorted patterned ground forms and the miniature forms (Washburn, 1979). Parameters such as freezing conditions (Nicholson, 1976), the size of stones in the coarse border (Washburn, 1979), and the spacing between pattern centres and borders (Goldthwait, 1976) have all been used to differentiate between large and small forms. Patterns with a mesh diameter or stripe width between 10 and 25 cm (Troll, 1944) or not exceeding about

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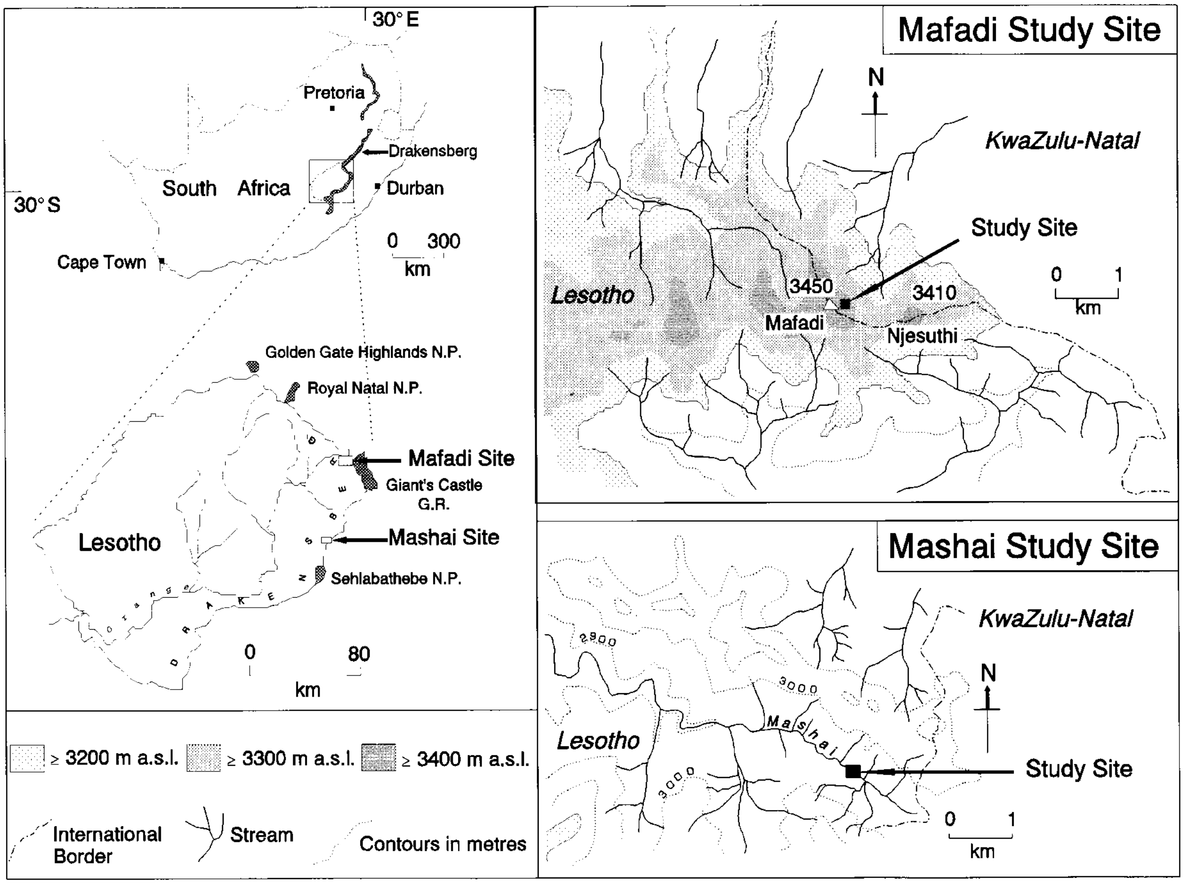

Figure 1. Location of study area

20 cm (Wilson and Clark, 1991) have, respectively, been regarded as small or miniature. This paper will use the classification given by Wilson and Clark (1991) and will refer to patterns with a mean mesh diameter or stripe width of under 20 cm as miniature.

Although sorted patterned ground has been the focus of much research worldwide (Warburton, 1990), little work of any substance has been produced regarding these landforms in southern Africa. Many researchers (Troll, 1944; Van Zinderen Bakker, 1965; Harper, 1969; Hastenrath, 1972; Hastenrath and Wilkinson, 1973; Dardis and Granger, 1986; Lewis, 1988a,b; Boelhouwers and Hall, 1990; Boelhouwers, 1991; Hanvey and Marker, 1992; Grab, 1992) have reported patterns such as sorted circles, polygons, stripes and non-sorted circles from the Drakensberg in southern Africa. Detailed assessments and quantitative data, however, are lacking. This information provides the first detailed account of miniature sorted patterned ground from an alpine region in southern Africa.

THE STUDY AREA AND METHODOLOGY

The Drakensberg basalts rise steeply from the interior of KwaZulu-Natal (South Africa) to form a natural border with Lesotho (Figure 1). Further to the west is the gently sloping mountain plateau of Lesotho. The high Drakensberg Escarpment attains an average altitude of almost 3000 m a.s.l. between Lesotho and KwaZulu-Natal, with Thabana-Ntlenyana (3482 m a.s.l.) as the highest summit.

Climatic records for the high Drakensberg are scarce. According to Grab (1994), the high plateau regions have a mean January air temperature of approximately 11°C and a mean July air temperature of 0°C. Mean minimum temperatures above 3000 m a.s.l. during the winter months (June to August) are commonly between

–4 and –7°C. An absolute minimum temperature of –20·4°C was recorded on 12 June 1967 at Letseng-la-Draai (3050 m a.s.l.). Precipitation is strongly seasonal: 70 per cent falls between November and March and less than 10 per cent between May and August (Tyson *et al.*, 1976). The zone of maximum precipitation along the main escarpment is believed to be between 2287 and 2927 m a.s.l., where approximately 1600 mm is received per annum (Killick, 1963). The escarpment also produces a rain shadow on the Lesotho plateau, where annual precipitation is reduced to about 600 mm. Snowfalls occur about eight times per annum and may be recorded during any month of the year. The general absence of snow and cloud cover during the winter months permits the localized development of frozen ground in the high Drakensberg (Grab, 1994).

Patterned ground was studied at two sites: Mashai Valley (2950 m a.s.l.) and Mafadi Summit (3410 m a.s.l.) (Figure 1). Terrain characteristics of altitude, slope aspect and slope gradient were determined at each site and pattern dimensions and sorting characteristics measured. Ten miniature sorted circles and 20 miniature sorted polygons were examined in river gravels adjacent to the Mashai Stream. At Mafadi Summit, ten miniature sorted plolygons were studied on non-sorted steps. The scarcity of well developed patterns does not enable larger sample sizes.

The percentage weight of a given particle size fraction in the polygonal pattern borders was compared against the same fraction in the pattern centres. A lateral-sorting index (*SI*) for each fraction in the patterns could then be calculated (modified after Ballantyne and Matthews (1983)), where:

$$S1 = \frac{Bo}{Ce}$$

Bo = percentage by weight of a given fraction in the border sample; *Ce* = percentage by weight of the same fraction in the centre sample. Where $SI = 0$ ‘perfect sorting’ occurs, with all material of a given size sorted into the centres; where $SI = 1{\cdot}0$ this indicates no lateral sorting of a given fraction; where $SI > 1{\cdot}0$ this indicates that a given fraction is deficient in the centre sample compared with the equivalent border sample.

This is the inverse of the sorting index introduced by Ballantyne and Matthews (1983, p. 344). Similarly, the percentage weight of a given particle size fraction at the polygonal pattern surfaces was compared against the same fraction at depth (subsurface). For these, a vertical-sorting index was calculated, where:

$$Sv = \frac{Su}{De}$$

Su = percentage by weight of a given fraction at the pattern surface; *De* = percentage by weight of the same fraction at depth (subsurface). Where $Sv = 0$ ‘perfect sorting’ occurs, with all material of a given size sorted at depth (subsurface); where $Sv = 1{\cdot}0$ this indicates no vertical sorting of a given fraction; where $Sv > 1{\cdot}0$ this indicates that a given fraction is deficient at depth (subsurface) compared with the equivalent surface sample.

PATTERNED GROUND CHARACTERISTICS

Miniature sorted circles

Although several periglacial studies have focused on sorted circles (e.g. Ballantyne and Matthews, 1982; Rissing and Thorn, 1985; Hallet and Prestrud, 1986; Washburn, 1989), few have examined miniature varieties. In the high Drakensberg, miniature sorted circles occur primarily near streams and wetlands, where adequate moisture is available throughout the year. The patterns sometimes form in river gravels where the microtopography is often irregular, but occur most frequently where the surface slope is between 0° and 3°. Patterns also occur on basalt steps near areas of ground seepage.

Two comparable varieties of miniature sorted circles were observed at the Mashai Valley study site. The first variety (A) consists of a fine cone-shaped centre which is enclosed by subrounded and blocky clasts and/or boulders (Figure 2). These commonly occur amongst boulders and clasts which are underlain by finer sediments. Hastenrath (1973) observed similar patterns on Mount Kenya and referred to these as ‘fine earth

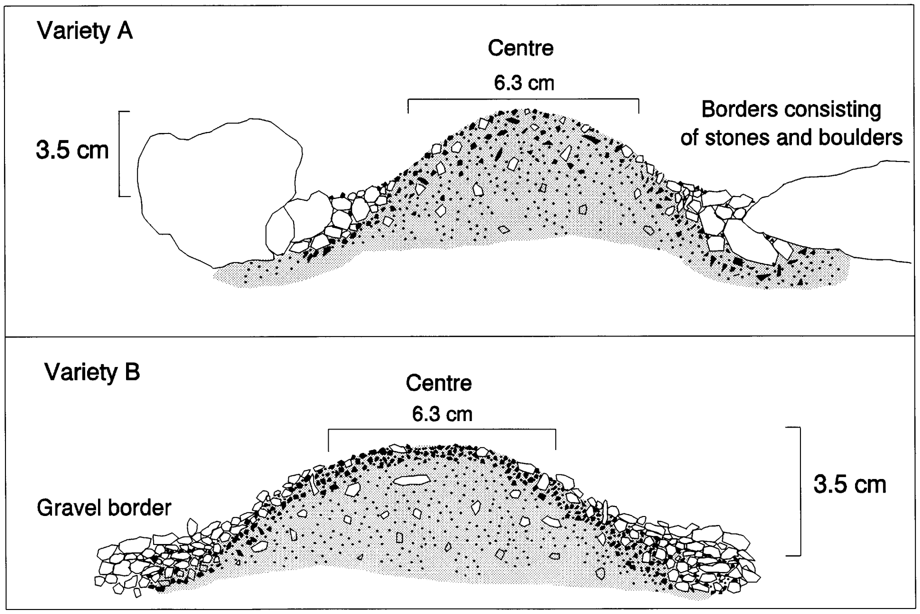

Figure 2. Sections through miniature sorted circles at Mashai Valley

mounds' (pp. 174, 175). The second variety (B) of circle pattern is characterized by raised and also cone-shaped fine centres, which are surrounded by coarse gravels and small pebbles (Figure 2). The centres of variety B patterns are raised about 3·5 cm and average 6·3 cm in diameter. Although most centres appear rounded, slight elongation sometimes occurs. Lateral sorting between centres and borders is evident, with the centres containing fewer pebbles and considerably finer particles than the borders (Figure 3). The clay/silt content for pattern surfaces is 0·3 per cent for centres and 0 per cent for borders (Figure 3). Sorting may occur to a depth varying between 1 and 1·5 cm.

Several characteristics may indicate that the circle patterns found at the Mashai Valley site are frost-sorted. Sorting characteristics (Figure 3) indicate lateral sorting, with medium and coarse gravels sorted into the borders, whereas finer material is more abundant in the circle centres. Other characteristics which may indicate frost action at the site are:

1. the occurrence of most patterns in groups rather than as individuals (Goldthwait, 1976);
2. elevated circle centres (Goldthwait, 1976; Washburn, 1979);
3. ice-cored circle centres during winter;
4. evidence of needle ice.

Miniature sorted polygons

Sorted polygonal patterns appear to be common in periglacial environments (Washburn, 1980) but are sometimes referred to as 'sorted nets' because of the irregularity and the absence of straight edges (Washburn, 1979; Ballantyne, 1987, 1991). In the Drakensberg, sorted circles and sorted polygons frequently occur in close proximity, and ultimately merge to form sorted nets. The patterns referred to here are more multi-angular than rounded in appearance, and shall, therefore, be referred to as miniature sorted polygons. Miniature sorted polygons have been reported predominantly from alpine regions such as the Rocky Mountains, USA (Butler and Malanson, 1989), the Scottish Highlands (Ballantyne, 1991), Kuh-i-Jupar, Iran (Kuhle, 1974), the Atlas Mountains, Morocco (Couvreur, 1973) and Mounts Kenya and Kilimanjaro, East Africa (Hastenrath, 1973). It is possible that Arctic and sub-Arctic regions, owing to extensive permafrost and intense frost action, host larger polygonal patterns than are commonly found in alpine regions. Further, the larger polygonal patterns appear to have received greater international attention than miniature forms in such high-latitude regions (e.g. Jonasson and Sköld, 1983; Hallet, 1990).

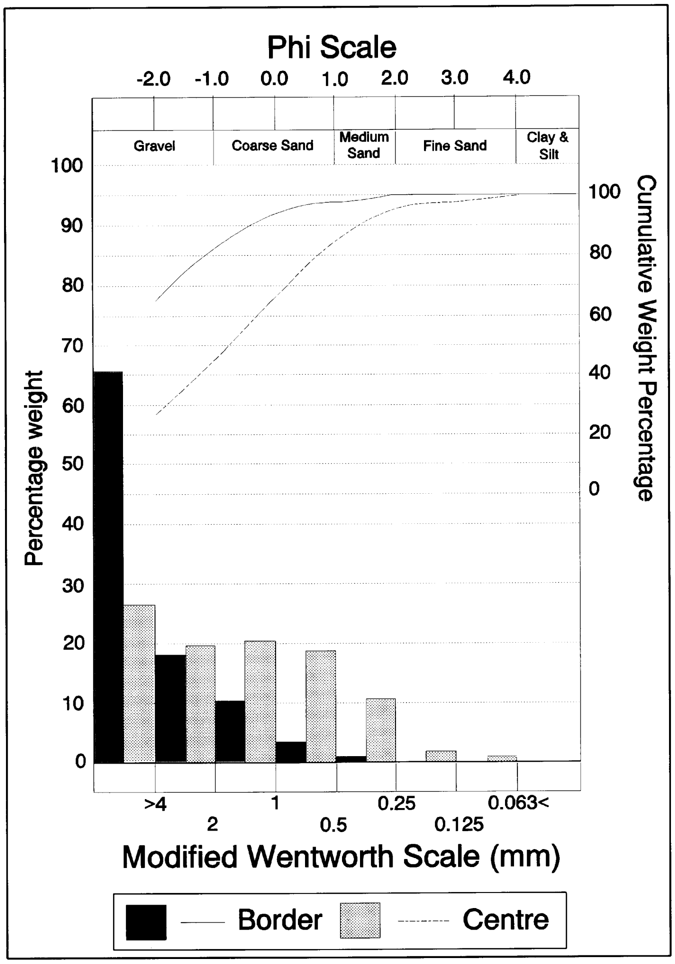

Figure 3. Mean particle size distribution for miniature sorted circles (variety B) at the Mashai Valley site. Number of samples = 20 (10 border; 10 centre)

In the Drakensberg, polygonal patterns have been recorded on the basaltic plateau as well as at lower altitudes in the Clarens Formation sandstones. Lewis (1988a) and Grab (1992) have reported patterns in sandstone tarns at altitudes of 2550 and 2420 m a.s.l., respectively. In the high Drakensberg, polygonal patterns are most commonly located within and adjacent to stream beds and ground seepage sites, but have also been reported from pan-shaped depressions (Hastenrath and Wilkinson, 1973).

Miniature polygonal pattern dimensions and characteristics for the two sites are given in Table I. Mean centre dimensions range from 11·6 cm (Mafadi) to 16 cm (Mashai), with a maximum value of 23·4 cm at Mafadi Summit (Table I and Figure 4). Centres become somewhat elongated downslope where the surface gradient is over 1°. At Mashai Valley, where patterns developed on a 3° surface, the mean cross-slope to downslope elongation is 1: 1·46, whereas at Mafadi no significant elongation occurs (1: 0·94), possibly because of the shallower 1° surface gradient (Table I). Wilson and Clark (1991) found an almost identical elongation of 1: 1·45 for miniature sorted nets in East Falkland where the surface gradient was 3° to 6°.

The mean distance between centres and the height of centres above the respective borders is similar between the two sites, despite a 460 m altitudinal difference (Table I). Although the centre height above the borders is commonly 3 cm, some patterns show little difference between border and centre height. This may result from rapid movement of gravels and coarse sand into the borders, accompanied by only slight heave of polygonal centres. The distance between centres (i.e. border diameter) is often considerable for such miniature patterns,

Table I. Dimensions and characteristics for miniature sorted polygons at Mashai Valley (n=20) and Mafadi Summit (n=10).

	Mashai site	Std Dev.	Mafadi site	Std Dev.
Sample size	20	–	10	–
Altitude (m)	2920	–	3380	–
Gradient (degrees)	3 (irregular)	–	1 (irregular)	–
Aspect (degrees)	40	–	60	–
Centre Diameter, Ds (cm)	18·9	2·97	11·4	6·38
Centre Diameter, As (cm)	13·2	2·62	11·9	3·66
Centre Diameter, mean (cm)	16	2·46	11·65	4·68
Ratio of As/Ds	1:1·46	0·26	1:0·94	0·32
Distance between centres (cm)	7·87	1·7	7·51	1·11
Centre height above border (cm)	2·66	0·57	2·81	0·96
Max. depth of sorting (cm)	6	–	7·3	–

Ds=downslope, As=across-slope

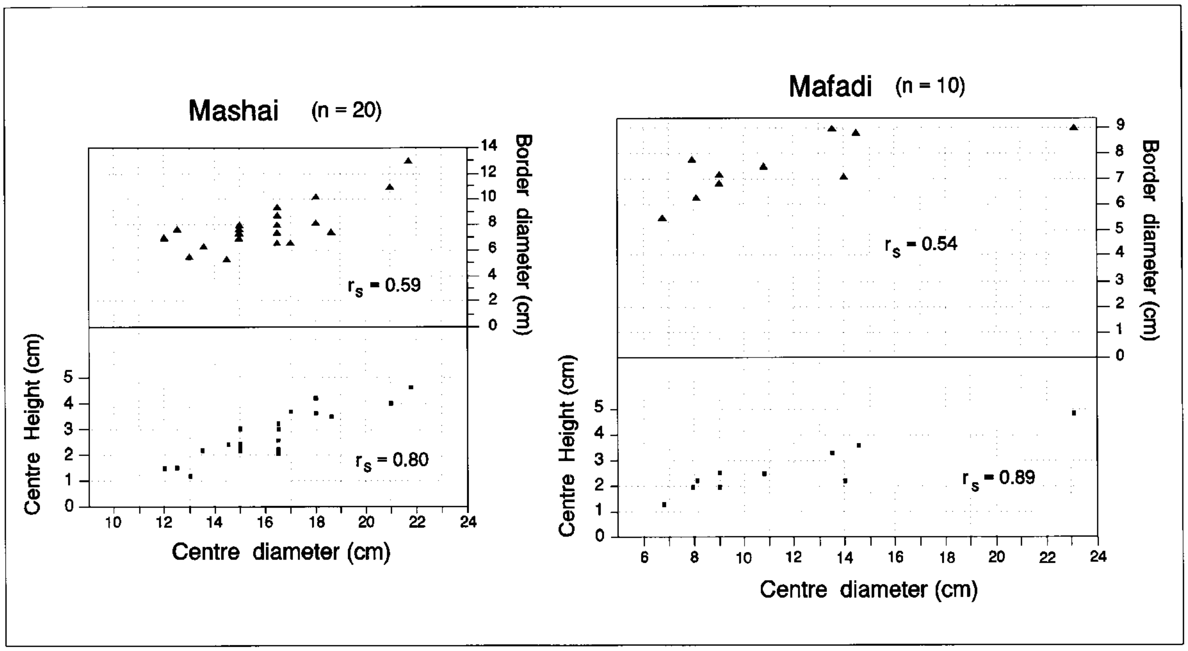

Figure 4. Correlating miniature sorted polygonal centre diameters with centre heights and border diameters

averaging 7 to 8 cm. As mentioned, this possibly occurs because of rapid migration of coarse particles towards pattern borders. As particles migrate towards borders, they bank-up against clasts already occupying the borders, consequently increasing the lateral dimensions of such borders. A positive correlation (r_s=0·59; significant at the 0·01 level) between polygonal border and centre dimensions was found at Mashai Valley; however, despite a similar value, no correlation was found at Mafadi Summit (r_s=0·54; not significant at the 0·01 level) (Figure 4). Both the Mashai and Mafadi patterns show a strong positive correlation (r_s=0·80 and 0·89, respectively, significant at the 0·01 level) between centre diameters and centre heights (Figure 4).

Although fine fractions are absent at the Mashai site, the patterns display sorting typical of such miniature patterned ground (Goldwait, 1976). Figure 5 shows how various particle sizes are sorted laterally and vertically. Samples were also taken midway between pattern centres and border centres. A gradual increase in the percentage of sand and decrease in the percentage of gravels occurs from borders to centres (Figure 5). The lateral extent of sorting is more pronounced at pattern surfaces than at 4 cm depth, as is also indicated by the sorting indices (Figure 5 and Table II). For instance, coarse to medium gravels (< –2 phi) have a lateral-sorting index (SI) of 2·5 at pattern surfaces and 2·1 at 4 cm depth, indicating that centres are more deficient of such particle sizes at the surface than at depth, relative to the adjacent borders. Conversely, finer sand and clay/silt is all sorted into centres at pattern surfaces (SI=0), but is marginally less explicit at depth (SI=0·1 to 0·5)

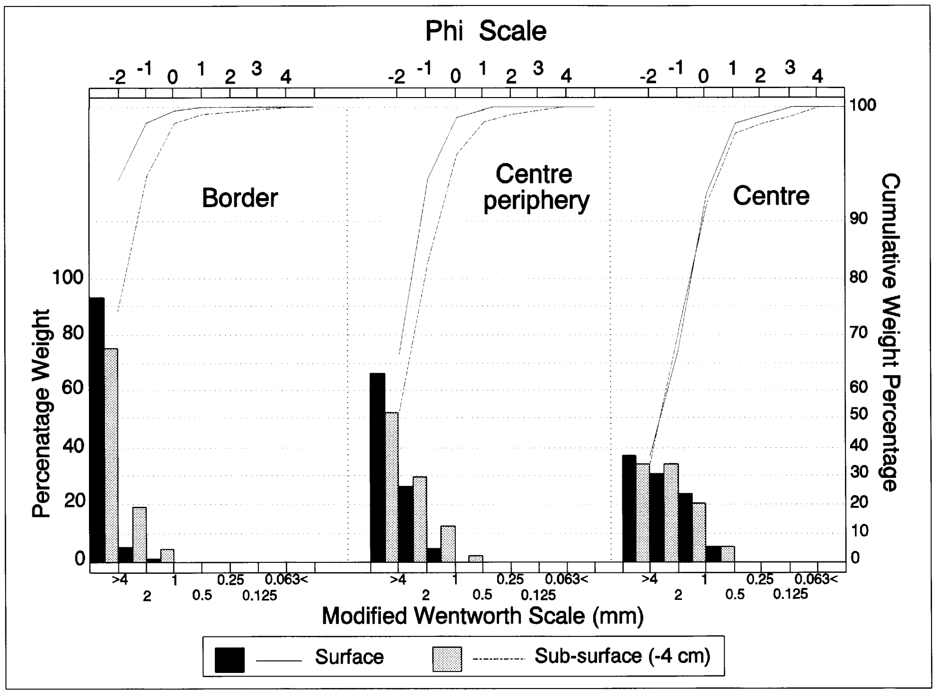

Figure 5. Mean particle size distribution for miniature sorted polygons at Mashai Valley. Number of samples = 60 (20 border; 20 centre periphery; 20 centre)

Table II. Sorting indices for miniature sorted polygons at the Mashai Valley (n=20) and Mafadi Summit (n=10) sites

	SORTING INDICES FOR POLYGONAL PATTERNS									
Mashai site										
Size grade (phi)	>–2	–1	0	1	2	3	4	4<		
SI surface	2·5	0·2	0·1	0	0	0	0	0		
SI subsurface (–4 cm)	2·1	0·6	0·2	0·1	0·1	0·3	0·5	0·5		
Sv centre	1·1	0·9	1·1	1	0·8	0·6	0	0		
Sv inter-border–centre	1·2	0·9	0·4	0·2	0·2	0	0	0		
Sv border	1·3	0·3	0·3	0·1	0	0	0	0		
Mafadi site										
Size grade (phi)	>–3	–2·5	–2	–1	0	1	2	3	4	4<
SI surface	25·5	6·6	0	0	0	0	0	0	0	0
SI subsurface (–4 cm)	–	–	1·3	0·9	0·9	0·8	0·7	0·7	0·5	0·4
Sv centre	–	–	1·1	1·2	1	0·8	0·6	0·7	0·6	0·5
Sv border	–	–	1·6	0	0	0	0·1	0·1	0·1	0

(Table II). The extent of vertical sorting increases progressively from centres to borders and attains a maximum depth of 6 cm at pattern borders. The depth of sorting at centres is seldom more than 1 cm. Vertical-sorting indices (*Sv*) show that for most size fractions in centres, values are close to 1·0, indicating no vertical sorting for these size fractions (Table II). Near-perfect vertical sorting, however, takes place at pattern borders where values for most size fractions approach 0 (Table II).

Sorting values for the Mafadi patterns show a very similar trend to those of the Mashai patterns (Table II and Figure 6). The percentage clay-silt for the Mafadi patterns is very much higher than that for the Mashai patterns, attaining a maximum of 17·2 per cent at 4 cm depth for pattern centres (Figure 6). Lateral sorting within a miniature polygonal centre was determined by taking samples at 2 cm intervals across the pattern centre (Figure 7). Gradual sorting across the centre is clearly evident, with a general decrease in the percentage of gravels and increase in the percentage of fines towards the midpoint of the pattern centre (Figure 7).

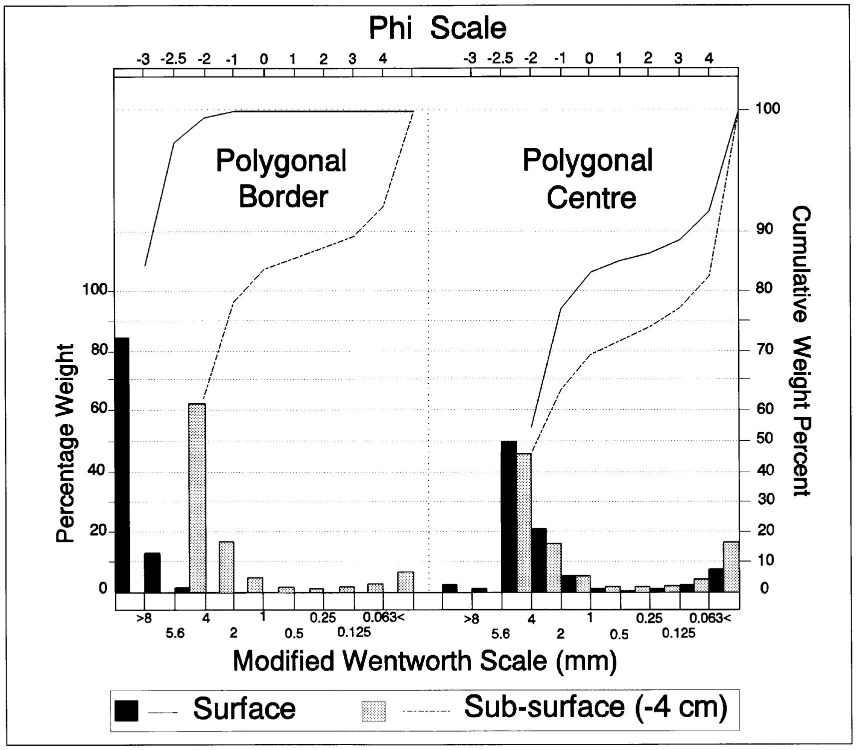

Figure 6. Mean particle size distribution for miniature sorted polygons at Mafadi Summit. Number of samples = 20 (10 border; 10 centre)

DISCUSSION

Possible processes

Desiccation and thermal contraction cracking are frequently considered to be primary controls for the development of some polygonal sorted patterns (Ballantyne and Matthews, 1983; Krüger, 1994). Polygonal patterns observed along the Mashai Stream begin to emerge in autumn when soils are still saturated, and are, therefore, unlikely to be initiated by desiccation cracking. It is more likely that desiccation cracking influences pattern development towards the end of winter, when soils dry out rapidly because of cold, dry and extremely windy conditions. Desiccation and polygonal crack development are, however, common on drier slopes and may be of significant importance in the development of polygonal patterns such as those found on the Mafadi Summit. Similarly, contraction cracking (Krüger, 1994) and/or convection cracking (Guangpan and Min, 1993) may help initiate pattern formation. The frost cracking model, however, only describes polygonal patterns (Krantz, 1990) and is, therefore, unlikely to explain the origin of circular patterns at the Mashai site.

Observations have shown that the accumulation of cobbles and gravel around circular centres of finer material is primarily the result of needle ice lifting material in the centres. Cobbles and gravel are then moved under the influence of gravity. In areas dominated by larger clasts and boulders, maximum heave occurs in the small gravelly/sandy areas within the blocky material, forming random associations of circular patterns.

Stream levels in the study area subside rapidly during April, leaving saturated sediments exposed and subject to rapid cooling. These factors commonly promote an uneven microtopography with heaved centres and depressions, possible initiated by differential swelling and frost-heaving (Van Vliet-Lanoë, 1988, 1991; Van Vliet-Lanoë *et al.*, 1990). Nicholson (1976) proposed that patterns may develop as a result of such an uneven microtopography, with the dome-shaped areas likely to undergo greater heave than the adjacent depressions, which in turn encourages new areas of heave. Observations from the Mashai Valley support such a formative process for polygonal patterns within river gravels. During April/early May of 1993 and 1994 it was observed

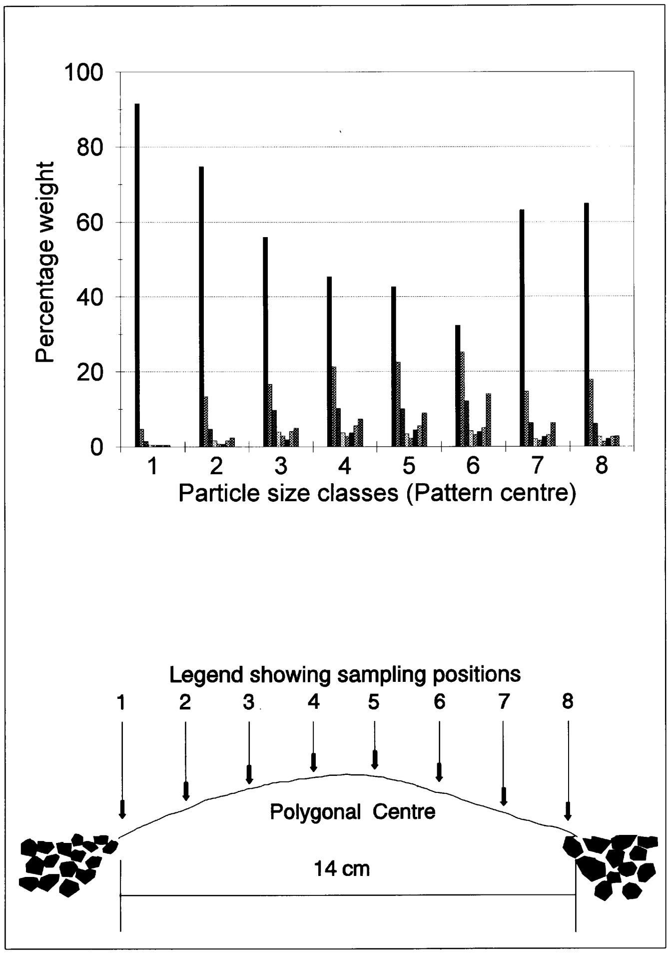

Figure 7. Sorting through a polygonal centre at the Mafadi Summit site. Samples were taken at 2 cm intervals through the centre. Size classes represented are from left to right: >4 µm; 4–2 µm; 2–1 µm; 1–0·5µm; 0·5–0·25µm; 0·25–0·125µm; 0·125–0·063µm; <0·063µm

that small sand banks adjacent and within stream beds developed uneven surfaces with raised areas and depressions, yet little sorting was visible (Figure 8). By late May/early June, the uneven surfaces flattened out, yet still showed irregularity, but now with more visible particle sorting. Coarser gravels occupied the depressions, whereas the raised areas consisted predominantly of finer gravels and sand. By mid-winter (July), much of the irregularity had disappeared, to be replaced by well-sorted polygonal patterns (Figure 9).

Moisture appears to be drawn towards the raised areas, where it freezes and ultimately increases the distance between soil particles (Guangpan and Min, 1993). These raised areas eventually become polygonal centres. Slight vertical sorting at centres is possibly the result of larger particles moving upwards (by the frost-pull process) in the direction of heat flow, relative to finer material (Anderson, 1988). Ballantyne and Matthews (1983) have suggested that the decline of coarser particles at pattern centre surfaces is not very rapid, primarily because clasts are continuously being heaved-up from below. Fines at centre surfaces may also be subjected to deflation, as a result of intense and frequent winds during the winter months. Such processes may help explain the slight downward fining of particles within pattern centres.

Lateral sorting appears to be induced by mechanical heave at centres, with gravels moving under gravity. Gradwell (1957) also reported that the growth and collapse of needle ice may result in coarse material migrating towards cracks (borders). As needle ice was found growing from within polygonal centres on several occasions, it is possible that it may have contributed towards particle movement away from such centres. Gradwell (1957) and Krüger (1994) have further suggested that rain-splash and/or rain-wash may aid such lateral sorting. The

Figure 8. Uneven surfaces with little visible sorting adjacent to the Mashai Stream at 2950 m a.s.l. in late April (Autumn) 1994

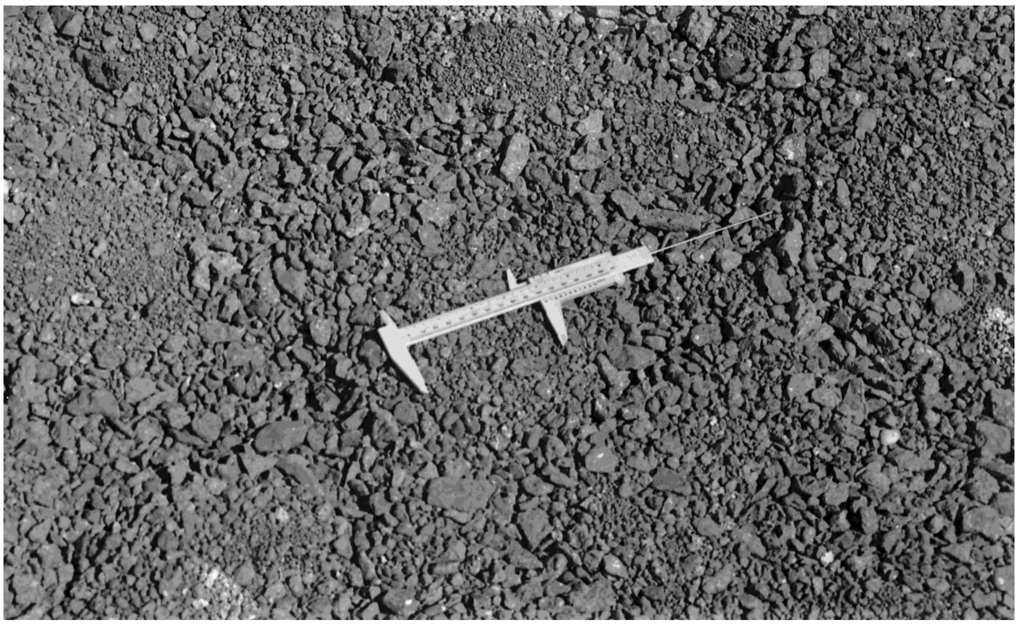

Figure 9. Well-sorted polygonal patterns adjacent to the Mashai Stream at 2950 m a.s.l. in July (mid-winter) 1994. The photograph was taken at the same locality as Figure 8

general absence of rain during the winter months would, however, exclude such rain-induced sorting mechanisms in the high Drakensberg. The movement of gravels towards borders eventually widens the borders, reduces the height difference between borders and centres and strengthens vertical sorting at borders. These seasonal miniature sorted patterns are ultimately destroyed by rain-splash, surface-wash, and other fluvial processes (e.g. stream flow) towards October and November.

Environmental implications

The absence of moisture during winter prevents widespread pattern development. Sites containing moisture throughout the year are usually found adjacent to rivers and streams where the microtopography is often steep, rendering such sites more suitable for striped patterned ground. A further limiting factor for the development of miniature sorted patterns is the absence of fines along such drainage zones. Site-specific factors such as surface

gradient and soil composition, depth and moisture are the primary controls for the development of miniature sorted patterns in this region. Altitudinal differences of 460 m on the summit do not appear to have influenced miniature pattern dimension. Such a finding may suggest that the near-surface soil freezing and thawing characteristics in the high Drakensberg alpine belt do not undergo significant change with altitude during the winter months. This could be attributed to a low lapse rate of only 3°C per kilometre in the alpine belt (Grab, in press). The size of miniature sorted patterns in the high Drakensberg is more likely to be determined by the localized soil moisture and particle size characteristics and the duration of pattern development and/or preservation.

Marques *et al*. (1990) have described some frost-related features such as ‘ice cementation, pipkrake and high laminar porosity and gaps around stones’ (p. 163), which emerged within four months after a fire in a Mediterranean zone. Similarly, miniature sorted patterned ground, thought to have emerged over a short time, has been described by Wilson and Clark (1991). No published accounts on recurrently forming, seasonal, frost-related patterned ground from other regions, however, have been found. The ability of frost-induced sorted patterns to develop within five to six weeks demonstrates the effect of regular, diurnal freeze–thaw cycles during the high Drakensberg winter months. Perennial miniature sorted patterns have only been observed at altitudes over 3200 m a.s.l. in the high Drakensberg. From the present distribution of seasonal and perennial miniature sorted patterns it would appear that at altitudes below 3200 m a.s.l., the present climate is less conducive to maintaining or preserving miniature cryogenic landforms during the wetter months. Most miniature sorted patterns in the high Drakensberg develop near wetlands, streams and ground seepage zones, and are consequently destroyed during the wetter seasons. The presence of primarily seasonal miniature sorted patterns is possibly the reason why most of these patterns are poorly developed. Clearly, fluvial processes during the warmer months dominate over cryogenic processes during the colder period, in surface modification.

CONCLUSION

The study has provided a first detailed assessment of miniature sorted patterned ground from the high Drakensberg in southern Africa. The patterns display elevated centres and sorting characteristics which are typical of those with a frost-related origin. Desiccation and thermal contraction cracking are thought to be primary mechanisms at the drier Mafadi Summit site, whereas differential swelling and frost heaving are proposed for the wetter Mashai Valley site. Altitudinal differences of almost 500 m in the alpine belt do not influence pattern dimensions in the high Drakensberg. Despite an exceptionally low percentage (<5 per cent) of fines at some sites, frost-induced sorted patterned ground may develop within five to six weeks. The rapid development of miniature sorted patterns clearly demonstrates the effect of regular freeze–thaw cycles during the winter months in the high Drakensberg. Contrary to most other cold environments where perennial miniature sorted patterned ground is found, the high Drakensberg patterns are seasonal landforms which recur annually, at exactly the same location.

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